TRANSMITTING ~~CODED~~ PACKETS WITHOUT IDENTIFYING THE CODE USED

The present invention relates to a method of transmitting digital packets that have been subjected to transmission coding, in which method the nature of the coding used is not transmitted.

The field of the invention is thus that of digital transmission by means of packets that might have been subjected to various codes, although these codes nevertheless all belong to a set of available codes. Thus, when a sender uses a transmission code for producing a packet from a message, it is important for the destination receiver for the packet to know how to identify the transmission code used so as to select suitable decoding means enabling it to recover the message. Although the field of application of the invention is very wide, it is described specifically with reference to digital cellular radio systems of the GSM type. These systems have the advantage of being widespread and the description of the invention is clarified by relating to a concrete example.

The common practice in digital telephony is for an analog speech signal to be digitized as 13-bit samples at a rate of 8 kHz, giving a rate of 104 kilobits per second (kbps). At present, GSM provides three types of source coding to reduce the data rate of this digital signal. Full rate coding, enhanced full rate coding, and half-rate coding produce respectively rates of 13 kbps, 12.2 kbps, and 5.6 kbps starting from the preceding signal.

After source coding which serves to compress speech, the signal is subjected to channel coding so as to protect it from the hazards of radio transmission.

Considering the association of source coding and channel coding as forming a single kind of coding, referred to as transmission code, the resulting signal

has a rate of 22.8 kbps at full rate and 11.4 kbps at half-rate.

That is the state of the art, but future systems have already been devised that will use numerous kinds of transmission code, with it being possible to modify the code during a call depending on the quality of the radio link. Since the messages are of fixed length in order to minimize technical complexity, provision is usually made for the different codes to produce packets that of the same length. Thus, the sum of the source coding rate plus the channel coding rate is constant. When the transmission channel is of good quality it is possible to adopt a relatively low data rate for the channel coding to the benefit of source coding, whereas in opposite circumstances, it is preferable to use channel coding that is more robust to the detriment of source coding. Naturally, propagation conditions can vary during a call so they can make it necessary to change the code used.

It is therefore appropriate to inform the receiver about the code that has been used for any given packet.

The immediate solution consists in reserving mode bits or positions within a packet for performing this function. Under such circumstances, the receiver begins by detecting the mode bits in order to determine which decoding means are appropriate for the transmission code that was applied by the sender.

Naturally, these mode bits must themselves be subjected to a special kind of coding, "mode coding", for the purpose of protecting them during transmission. Unlike transmission coding, mode coding must be unique so that the receiver can identify the transmission coding used without ambiguity. The mode bits must therefore be coded independently of the payload of the message which is subjected to transmission coding. This mode coding is naturally designed for the most severe transmission conditions and it is common practice to use a convolutional code for this purpose.

By way of reminder, such a code produces, for a given bit, a number N of polynomials of degree K. Conventionally, the code rate is written 1/N and the constraint length of the code is written K. With a bit being indexed by its position in the message, a polynomial P associated with bit b_i is defined by coefficients a_j and is presented in the form of the following sum modulo 2:

[2] $$P = a_0 b_i + a_1 b_{i-1} + a_2 b_{i-2} + \ldots + a_{k-1} b_{i-k+1}$$

It is commonly accepted that to obtain satisfactory decoding, the minimum length of the coded word must be equal to five times the product of the constraint length multiplied by the inverse of the coding rate. Thus, for a rate of 1/3 and a constraint length equal to 5, suitable typical values, the minimum size for the coded mode is 75 bits. It can be seen that if four transmission codes are provided, information which requires two mode bits, it is necessary to use 75 bits of the packet to transmit this information under the best conditions.

If transmission efficiency is defined as the ratio of the number of bits carrying information to be transmitted over the number of bits transmitted, it can be seen that this efficiency is far from good.

Thus, US patent No. 5 230 003 teaches a decoding system designed to distinguish between signals coded using different available codes, with the code used not being transmitted. In that system, a decoder is required for each available code. The number of decoders can become large when numerous codes are used.

An object of the present invention is thus to provide a method of transmitting coded packets which does not penalize transmission efficiency while nevertheless limiting the complexity of the system.

According to the invention, receiver equipment is provided to receive a digital packet that has been subjected to transmission coding selected from a

plurality of available codes, the equipment including decoding means for decoding said packet as appropriate for said transmission coding; for the transmission coding belonging to a small set of possible codes, the equipment comprises for each of said possible codes a decoder receiving a portion of said packet to determine an associated decoding reliability, and it further comprises means for identifying said decoding means as the means corresponding to the decoder that has produced the best reliability.

The invention also provides transmitter equipment for transmitting a string of coded messages by means of packets, the last message of said string being subjected to identified coding from a set of available codes and different from the coding applied to the first message of the string, said packets comprising firstly a payload section for receiving data and secondly guard bits, said equipment having means for arranging each of said coded messages within the entire payload section of the corresponding packet; and in addition the coding applied to said last message belongs to a small set of possible codes.

Preferably, the first packet of a transmission is subjected to a predetermined available code.

Furthermore, the possible codes are the available code following the code of the preceding packet, the available code which is identical thereto, and the available code which precedes it.

Advantageously, the possible codes are convolutional codes each having a distinct code scheme.

It is then desirable for the code schemes to differ in code rate.

In addition, when the equipment is for use in reception, if the possible codes are three in number, then the decoding means can be identified by means of two coding rates.

The invention is described below in greater detail as embodiments given by way of example and with reference to the accompanying figures, in which:

- Figure 1 is a block diagram of a receiver enabling the invention to be implemented; and
- Figure 2 is a diagram of a transmitter enabling the invention to be implemented.

In the invention, the mode specifying the transmission code to which a packet has been subjected is not transmitted by the transmitter.

In the embodiment below, four transmission codes are available, each identified by a mode number 1, 2, 3, or 4. Each transmission code has a total rate of 22.8 kbps and associates source coding and channel coding; the following numerical example is given:

- mode 1: source = 12.2 kbps channel = 10.6 kbps
- mode 2: source = 9.2 kbps channel = 13.6 kbps
- mode 3: source = 7.8 kbps channel = 15.0 kbps
- mode 4: source = 6.5 kbps channel = 16.3 kbps.

Mode is selected as a function of the estimated signal-to-noise ratio over the link between the transmitter and the receiver. This ratio is thus the result of measurements performed in the receiver and returns to the transmitter so as to enable it to select the coding that is appropriate for transmission. Measuring signal-to-noise ratio is part of the state of the art so it is not described in greater detail.

Using the same data as above, the transmitter selects one of the modes as a function of the estimated signal-to-noise ratio C/I as follows:

- mode 1: 13 dB < C/I
- mode 2: 10 dB < C/I < 13 dB
- mode 3: 7 dB < C/I < 10 dB
- mode 4: C/I < 7 dB.

Furthermore, after source coding has been applied to a given source word, convolutional channel coding of the

various modes produces packets having the following characteristics:

· mode 1: 318 bits at rate 1/2 followed by 138 bits at rate 2/3

· mode 2: 222 bits at rate 1/3 followed by 234 bits at rate 1/2

· mode 3: 384 bits at rate 1/3 followed by 72 bits at rate 1/2

· mode 4: 324 bits at rate 1/3 followed by 132 bits at rate 1/4.

The receiver is designed to decode any of the modes by using the Viterbi algorithm. For an analyzed word, the Viterbi algorithm produces a decoded word plus a metric. The metric gives the distance between the analyzed word and a reference word which, on being subjected to the same algorithm, produces the same decoded word. This metric is thus a measure of the reliability of the decoding.

The maximum likelihood detection algorithm operates on the basis of a coding scheme that is fully specified, specifically in terms of code rate, polynomials used, and the positions within the packet of the various code bits. For various possible bit strings, it calculates the metrics they present relative to the analyzed word and finally retains the bit string having the greatest metric.

Thus, when the algorithm is implementing a coding scheme that does not correspond to the coding used for the word being analyzed, the various bit strings present metrics that are substantially similar. However, if the coding scheme used is appropriate for the analyzed word, then a particular bit string will present a metric that is much greater than the others, and that is therefore the solution string.

The difference between the minimum metric and the maximum metric decreases with increasing decorrelation

between the coding parameters and the decoding parameters.

It is thus appropriate to select the channel codes of the various modes in such a manner as to present correlation that is as small as possible. In this respect, several dispositions can be used.

Firstly, provision can be made for all of the bits of a packet to be inverted, e.g. in modes 2 and 3.

Secondly, it is preferable to use different polynomials for each of the modes and to order them differently.

Thirdly, it is recommended to adopt different code rates, wherever possible.

The receiver thus takes advantage of the disparities between the various channel codes to detect the transmission code used for a received packet. To this end, it attempts to decode the packet using each of the channel codes and it retains the code that outputs the greatest metric.

It should be observed firstly that it is not necessary to decode an entire packet using all four possible codes in order to achieve satisfactory detection. It suffices to act on a significant fraction of the packet, e.g. the first portion.

It should also be observed that the number of possible codes in a packet can be restricted compared with the four available codes. By way of example, a received packet can have only the same mode as the preceding packet, or a mode immediately following or preceding that of the preceding packet: a mode 4 packet can be followed by a packet in mode 3 or 4, while a mode 2 packet can be followed by a packet in mode 1, 2, or 3. Furthermore, the first packet to be received can necessarily be in mode 4 so that there is no ambiguity at the beginning of transmission.

With reference to Figure 1, the receiver is described below in greater detail. The receiver

comprises a truncating circuit TR which receives a packet B and retains a portion S thereof, specifically the first 138 bits in the present case. The receiver stores in memory the coding mode Pr used for the preceding packet.

It has a first decoder DEC1 which decodes the portion S of the packet using mode (Pr-1) to produce the corresponding metric Met(Pr-1).

It has a second decoder DEC2 which decodes the portion S of the packet in mode Pr to produce the corresponding metric Met(Pr).

It has a third decoder DEC3 which decodes this portion S using mode (Pr+1) to produce the associated metric Met(Pr+1).

It should be observed at this point that when Pr is equal to 1 the first decoder DEC1 is not useful in which case Met(Pr-1) can be forced to zero. Similarly, if Pr is 4, the third decoder DEC3 is not of interest and its output metric Met(Pr+1) can likewise be made zero.

Furthermore, the person skilled in the art will observe that the three decoders shown here as distinct entities could very well be implemented by means of a single processor for performing Viterbi algorithm processing, said processor being parameterized in modes (Pr-1), Pr, and (Pr+1) to perform the functions of the first, second, and third decoders DEC1, DEC2, and DEC3, respectively.

The receiver also has a comparator circuit COMP which looks for the winning mode m that produced the greatest metric:

$$Met(m) = Max[Met(Pr-1), Met(Pr), Met(Pr+1)]$$

As a precaution, it can be advantageous when searching for the winning mode m to ensure that it does indeed produce a metric that is significantly greater than the smallest metric, e.g. that is twice the smallest metric. If that is not the case, it is reasonable to declare that the winning mode m is the same as the preceding mode Pr. In any event, if it is not possible

to distinguish easily between the three decoders, it is highly probable that the packet in question is not usable.

This receiver naturally has decoding means MD which receive the entire packet B to produce a decoded word by applying the Viterbi algorithm with the parameters of the winning mode m.

Here again, these decoding means need not necessarily be implemented as an independent circuit. Advantageously, it is possible to reuse the same processor as is also used to replace the other three decoders.

Furthermore, these decoding means can be restricted to decoding only that portion of the packet which has not already been decoded by the decoder that produced the greatest metric.

Now that the general principle of the receiver is described, the description below relates to ways in which this principle can be adapted to take advantage of the specific features of the codes mentioned above.

It can easily be seen that the three decoders can be replaced by two modules performing Viterbi decoding on 72 bits, the first at a rate 1/3 producing a metric M3 and the second at a rate 1/2 producing a metric M2.

Similarly, the comparator circuit COMP can be simplified so as to establish a decision value F showing which of the two metrics M2 and M3 wins. For example, using the notation p for a predetermined weighting coefficient, this decision value F takes the following values:

- if $M3 - p.M2 \geq 0$, then $F = 3$
- if $M3 - p.M2 < 0$, then $F = 2$.

Thus, when the preceding mode Pr is 4, it suffices to analyze the first 72 bits of the packet with the two modules. If the decision value F is 3 then the winning mode m is mode 4, whereas if this value is equal to 2, then the winning mode is mode 3.

When the preceding mode Pr is 3, then the two modules are again loaded with the first 72 bits of the packet. If the decision value F is 3, then the winning mode m is the only possible mode having the rate 1/3, i.e. mode 4. However, if the decision value is equal to 2, then the two modules are loaded with the following 72 bits of the packet. If the new decision value F is 3, then the winning mode m is mode 3, whereas otherwise the winning mode is mode 2.

When the preceding mode Pr is 2, account is taken of the 72 bits following the 138th bit of the packet. If the decision value F is 3, then the winning mode m is the only possible mode having the rate 1/3, i.e. mode 3. However, if the decision value is equal to 2, then both modules are loaded with the 72 bits following the 234th bit of the packet. If the new decision value is 3, then the winning mode m is mode 2, and otherwise the winning mode is mode 1.

Finally, when the preceding mode Pr is 1, then both modules are loaded with the 72 bits following the 234th bit of the packet. If the decision value F is 3, then the winning mode is mode 2, whereas otherwise the winning mode is mode 1.

It can thus be seen that the invention can be implemented in many different ways that cannot be listed exhaustively. The important point is to search over one or more portions of the packet for the mode that gives the best decoding reliability, e.g. by means of the corresponding metric.

The various modes differ in this case in that they have code rates that differ depending on the position of the bit in the packet. It is also possible to envisage differentiating the modes by the coding polynomials which are allocated to them. It is also possible to act on the positions of the coded bits in the packet. To sum up, it is appropriate for the different modes to present

distinct coding schemes, whether in terms of code rate, kind of polynomial, or code bit positions.

Furthermore, the invention applies regardless of the types of coding used and it is not limited to convolutional codes. The only important point is to be able to distinguish reliably on reception between the codes that might be applied to a received packet by looking amongst the possible codes for the code from which the packet is most probably derived.

The invention also provides a transmitter designed to transmit packets to a receiver.

The transmitter has the advantage of being simplified since it does not transmit the transmission code it has used for the packet.

It is appropriate at this point to recall that a packet results from coding in succession a header section, a payload section, and a tail section. The use of a convolutional code of constraint length K makes it necessary to use (K-1) guard bits in the header section and the same number of guard bits in the tail section. The guard bits thus bracket the payload section.

The payload section corresponds to the portion that can be used, it being understood that the guard bits cannot serve to carry information. The guard bits are predetermined and are used only during decoding.

In the invention, the entire payload section can be used for carrying data to be transmitted from the transmitter to the receiver. The transmission code is not specified in the payload section, even when the code has changed compared with the preceding packet.

With reference to Figure 2, the transmitter thus comprises a control circuit CC which receives the code N to be applied to the message W that is to be conveyed by means of the next packet. The transmitter also has a coder member COD which receives the message W to encode it as a function of coding parameters Pa provided by the control circuit CC. Specifically, the control circuit CC

produces the coding scheme as a function of the required channel coding.

The transmitter also has a register U which corresponds to the payload section of the packet. This register is completely filled with the coded message MC coming from the coder member COD.

The other components of the transmitter are not described in greater detail since they belong to the state of the art.

The above-described implementation of the invention is naturally only an example. The person skilled in the art has numerous ways of implementing the invention differently, for example merely by replacing one means by an equivalent means.